

Table 1. Prospects in Juncos quadrangle Aggregate width in Laboratory serial Location by Length of Ore minerals Type of no. of prospects Name of meters of mineralized prospect Puerto Rico coorprospect ock exposed at prospect sampled (see table 2 on map dinates' (meters) (in meters) for analyses) or trench North West 45,715 199,060 Magnetite, hematite 271,981 Magnetite, hematite 271,978 45,170 201,140 Float 45,160 201,915 45,150 201,920 17.2 9.8 Escuela No. 2 271,979 Cane Field No. 1 44.935 202.040 Hematite, magnetite 44.820 202.070 271,980 44,525 202,075 Aguayo No. 3 45,050 202,455 Trench 45,045 202,470 6.8 Magnetite, malachite Aguayo Nos. 2, 5 Trench 5 8.6 1.2 14.6 Magnetite, malachite, 271,987 Aguayo No. 1 45,045 202,490 cuprite, limonite 45,050 202,505 9.2 Aguayo No. 4 44,960 202,520 Outcrop Hematite, magnetite 44.740 202.300 Outcrop Hematite, magnetite 13 271,989 44,690 202,560 Outcrop Hematite, magnetite 44,375 202,310 Hematite, cuprite(?), Pastor No. 1 magnetite, malachite 271,977 44,315 202,400 5.4 Pastor No. 2 Malachite, azurite, chalcocite(?) 44,315 202,420 Malachite, azurite Pastor No. 3 10.8 Torres No. 1 44,220 202,410 271.974 44,210 202,450 Roadcut 44,210 202,480 8.0 Limonite Santiago No. 1 44.195 202,485 Santiago No. 2 27.2 Santiago No. 6 44,225 202,500 Magnetite, malachite 20.2 44,215 202,520 Limonite, malachite Santiago No. 3 24.2 29.5 7.2 44,180 202,535 Magnetite Santiago No. 4 Magnetite, malachite Santiago No. 5 44.180 202.630 44,930 202,755 Magnetite Suiza No. 3 Trench Magnetite 44.895 202.780 Trench Suiza No. 2 45.5 Magnetite Suiza No. 4 44,900 202,810 Two trenches Magnetite, malachite Suiza No. 1 44,930 202,805 Suiza No. 5 44,905 202,840 Magnetite 44,920 202,850 30.5217,982 Magnetite, hematite Suiza No. 6 Trench 44.820 202,925 Outcrop Magnetite 45,470 203,100 Trench 13.7 45,425 203,125 0.75 Trench Magnetite, hematite 23.8 271,975 45,415 203,145 Trench Magnetite, hematite, 45,385 203,160 Limonite 45,365 203,165 7.8 Magnetite, malachite, Trench hematite 16.8 Limonite, hematite 45,315 203,180 45,335 203,210 14.8 45,290 203,200 Trench 271.976 45,270 203,210 15.0 Malachite, magnetite 44,915 203,235 271,988 Trench Magnetite, limonite(?) 44,765 203,560 Outcrop Magnetite, chalcopyrite, malachite Magnetite, hematite 44,850 203,985 271,985 Magnetite, hematite 44,880 204,130 La Caridad Outcrops 44,850 204,230 Magnetite, hematite 271,986 44,850 204,350 Outcrop Magnetite 44,790 206,150 Limonite Trench 44,790 206,165 Limonite Keystone mine 44,330 209,030 170 Magnetite, hematite, 271,972 malachite, azurite, (main pit) chrysocolla, cuprite, chalcopyrite 271,973 44,270 209,205 Stockpile of Keystone mine Magnetite, cuprite malachite, azurite,

DATUM IS MEAN SEA LEVEL INTRODUCTION The geology and mineral deposits of the Juncos quadrangle have been studied by the U.S. Geological Survey as part of a cooperative project with the Puerto Rico Economic Development Administration. The Juncos quadrangle is of economic interest because it contains the largest deposit of iron ore known in Puerto Rico. The Juncos quadrangle lies in east-central Puerto Rico between longitudes 65°52'30" and 66°00' W. and latitudes 18°7'30" and 18°15' N. (See Index map of Puerto Rico). The northwestern corner of the area is about 27 kilometers airline southeast of San Juan and 4 kilometers eastnortheast of Caguas. The quadrangle occupies an area of 183 square kilometers and includes parts of the Municipios of Gurabo, San Lorenzo, Juncos, and Las Piedras. Paved highways provide access to most of the

In 1916 the geology of the Juncos quadrangle was mapped by Charles R. Fettke (1924b) under the auspices of the New York Academy of Sciences and the Government of Puerto Rico. The quadrangle comprises the northwestern part of Fettke's Humacao district which includes the southeastern part of the Island. A narrow strip along the northern part of the quadrangle was mapped in 1925 by Howard A. Meyerhoff (1931) as part of his study of the Fajardo district. The Keystone mine, 2.5 kilometers east of Juncos, was described by Fettke (1924a). Several unpublished reports on the iron ore deposits of Puerto Rico by consulting geologists and mining engineers include detailed reports on this mine (Roberts and Crago, 1945, and Heidenreich, 1955). A report on the geology and ore deposits of the mine by Leovigildo Vázquez of the Puerto Rico Department of Industrial Research is in preparation. The quadrangle was investigated during the period of 1954-56 by James P. Owens, assisted by Robert B. Guillou, as part of a petrologic study of the large complex of plutonic rocks exposed in the southeastern part of of the island. Geologic studies of the area were started by the writer in September 1956, and continued until the latter part of March 1957. In 1959 the writer studied several prospect trenches opened by the Caguas Copper Co. in barrios Jaguar and Mamey, Municipio de Gurabo.

GENERAL GEOLOGY Most of the Juncos quadrangle is underlain by the San Lorenzo batholith, a large mass of plutonic rock, which, in the quadrangle, consists predominantly of granodiorite. The granodiorite is bordered on the northwest and north by metamorphosed volcanic rocks of probable Cretaceous age into which it has been intruded. These rocks are overlain by unconsolidated surficial deposits, which are most extensive in and adjacent to the larger stream valleys. Volcanic rocks.-The volcanic rocks in the Juncos quadrangle consist of metamorphosed lava flows and flow breccias; bedded volcanic siltstone, sandstone, and breccia; and impure limestone. The volcanic rocks crop together with the surficial deposits, occupy about one-third of the quadrangle. They are bounded on the south and east by granodiorite and associated rocks of the San Lorenzo batholith, but east of Juncos the boundary is concealed by surficial deposits. The volcanic rocks are also magnetite, apatite, sphene and in some specimens microcline, zircon, and at 18 localities in and adjacent to the zone of calc-silicate rock. Ore intruded by numerous dikes and stocklike masses of gabbro and diorite, and quartz monzonite dikes. Most of the volcanic rocks are lava flows and volcanic sandstone. The flows consist of massive porphyritic lava and breccia of andesitic composition. The most abundant extrusive rock is greenish-gray augite in composition from diorite to gabbro. The diorite is a medium- to

A belt of lenticular deposits of iron ore extends east-southeastward present in an iron-ore lens about 1.7 kilometers west-southwest of andesite composed of phenocrysts of augite and plagioclase in a ground-

mass of altered plagioclase and ferromagnesian minerals. In some plagioclase and hornblende and minor quartz and relict pyroxene; accesplaces the lava is nonporphyritic and amygdaloidal; most of the amygdules are filled with quartz and epidote or calcite. Closely associated with the extrusive rocks are masses of unstratified, possibly tuffaceous, rock that in part is lighter colored than the adjacent extrusive rocks. The most common unstratified sedimentary rock is a greenish-gray volcanic sandstone composed of crystals of augite and plagioclase in a matrix of ferromagnesian minerals and feldspar. Another type, tuff breccia, consists of large angular to subangular fragments of lava, up to 20 centimeters long in a fine-grained reddish-brown or greenish-gray matrix of chloritized volcanic material. Southwest of San Lorenzo and at several places near the northern

border of the quadrangle, stratified clastic rocks consist mainly of volcanic breccia, sandstone, and siltstone that are, generally, of greenishgray color. In areas of outcrops, the attitudes of these rocks are indicated on the map by strike and dip symbols. Lenses of impure limestone as much as 30 meters thick crop out discontinuously in the northern part of the quadrangle. Most of the limestone contains considerable volcanic debris. A few fragmental fossils observed. in the limestone suggest a Cretaceous age (N. F. Sohl, written At places near the intrusive border the volcanic rocks have been metamorphosed in part to an epidote-actinolite hornfels in which relict textures are preserved and in part to a completely recrystallized rock of the pyroxene hornfels facies which is characterized by porphyroblasts of

diopside. Both rocks have a granoblastic groundmass composed of plagioclase, diopside, and hornblende with magnetite as an accessory mineral. In areas relatively close to dikes and stocks of dioritic rock the limestone has been altered to marble, amphibolite, calc-silicate rock, and lenses of iron ore that are composed largely of magnetite or magnetite and hematite. The calc-silicate rock is a greenish-gray rock composed chiefly of porphyroblasts of diopside in a granoblastic groundmass of diopside and hornblende with interstitial patches of tremolite and garnet; accessory minerals include calcite and apatite. In places this rock consists almost entirely of epidote and garnet. Although the iron ore lenses consist principally of magnetite or magnetite and hematite, they commonly contain variable amounts of garnet, epidote, and quartz. Intrusive rocks.—The southern and eastern parts of the Juncos quadrangle are underlain by granodiorite. This rock is the northwestern part of the San Lorenzo batholith, the largest exposed body of plutonic rock in Puerto Rico. In the west-central and northern parts of the quadrangle more basic igneous rocks have intruded the volcanic rocks as dikes and small stocks. Small bodies and dikes of quartz monzonite have intruded granodiorite and volcanic rocks alike along the margin of the batholith, and also dikes of porphyritic hornblende andesite intrude

the volcanic rocks. with granitic texture. The rock commonly has a pinkish cast produced by the potash feldspar. The principal minerals are oligoclase-andesine, potash feldspar, quartz, hornblende, and biotite; accessory minerals are Table 2 shows spectrographic and chemical analyses of samples taken two debris-avalanche deposits shown on the map. corundum(?). A characteristic of the outcrop area of the granodiorite minerals identified include limonite, magnetite, hematite and small ing 10 meters in length and 3 meters in width. The largest exposed lens is the abundance of very large boulders, many as much as 12 meters in The basic dikes and stocklike bodies cutting the volcanic rocks range assay methods; paladium was found in one and platinum in another. coarse-grained rock with a granitic texture; its principal minerals are across the Juncos quadrangle from the Jaguar stock to the hills just Cantagalio. The occurrence of malachite, azurite, and chrysocolla can

sory minerals are magnetite, biotite, apatite, and sphene. The gabbro is crops out just north of the San Lorenzo batholith in the Juncos and with the low-grade iron ore. texturally similar to the diorite but it contains a higher percentage of Humacao quadrangles. The only deposits that have been exploited in the pyroxene; an average sample is composed principally of labradorite, Juncos quadrangle are the Keystone mine and to a small extent the La augite, and hornblende and minor magnetite and apatite; accessory minerals include quartz and sphene. The quartz monzonite that occurs along the margins of the batholith mine, is believed to be the largest deposit of iron ore in Puerto Rico. is a fine- to coarse-grained pink to white rock varying in texture from Most of the early exploration of this deposit was done by J. S. Elliot in fine-grained to granitic. It is composed of roughly equal parts of quartz, 1904 for the Spanish American Iron Co. (Resumé of report by Elliot in orthoclase, and oligoclase; accessory minerals are biotite and magnetite. Hydrothermally altered rocks.—Several small bodies of hydrothermally ogists examined the deposit, but no important additional exploration altered rock crop out in the northern part of the quadrangle. The large was carried out other than a magnetometer survey made by Jackson

Surficial deposits.—Unconformably overlying the bedrock in the quadmined by this company from a deposit near Humacao. Because of the rangle are unconsolidated deposits of clay, silt, sand, gravel, cobbles, variable grade of the ore, the lenticular shape of the ore bodies, and the and boulders, which have been differentiated on the map into piedmont fan and alluvial terrace deposits, alluvium, and debris avalanche deposits. the remaining reserves in the mine. Stratigraphy and structure.—The only attitudes observed in the Juncos quadrangle are in the stratified rocks southwest of San Lorenzo and open cut about 40 meters east of the main pit. The ore occurs in lenticular near the northern border of the quadrangle. In both areas the dips are or tabular bodies at two stratigraphic positions. Nearly all the ore mined northerly. The volcanic rocks and possibly the intrusive rocks have at the main pit came from the upper zone. Parts of the bodies exposed in been cut by numerous faults of unknown magnitude and displacement. However, only two faults were mapped; these were observed at the Keystone mine, 2.5 kilometers N. 80° E. of Juncos. It is believed that some of the offsets observed in the limestone and calc-silicate rock in the northern part of the quadrangle may be due to faulting. The stratigraphic relations of the layered rocks in the Juncos quadrangle were not mapped because most of these rocks have been at least partially metamorphosed, and in weathered outcrops which are characteristic of the Juncos quadrangle, the distinguishing primary features are not preserved. However, it is expected that geologic mapping in adjacent quadrangles where rocks are less metamorphosed and structure is less complex will provide the information needed to determine the

Juncos quadrangle. ECONOMIC GEOLOGY Resources of possible economic value in the Juncos quadrangle include iron and copper minerals, crushed stone, and sand and gravel. Iron and copper minerals.—Exploration, chiefly for iron but also for calcareous unit is cut off by a major cross fault, and no evidence of the 1904. As many of the prospects of these companies as could be located have been marked on the geologic map and listed in table 1 of this report. the mine. Much massive iron ore also occurs south of the mine in the amounts of malachite, azurite, cuprite, and chrysocolla. Traces of gold of ore is at La Caridad prospect and silver were also detected in three of five samples tested by the five Small quantities of malachite and a little chalcopyrite, chrysocolla, and

stratigraphic sequence and to interpret the geologic structure in the

Caridad prospect about 21/2 kilometers N. 68° W. of Juncos. The Keystone mine, also called La Mina, La Esperanza, and the Juncos Roberts and Crago, 1945). Between 1904 and 1951 engineers and geolbody at Cantagallio is part of a belt of quartzose, alunitic, and pyrophyllitic in 1933 (in Roberts and Crago, 1945). Roberts and Crago (1945, p. 8) rocks traced eastward from Cerro La Tiza by Smith and Hildebrand estimated that a possible reserve of 850,000 long tons of direct-shipping (1953). Typically the hydrothermally altered rock is mottled white, buff ore and concretrates could be obtained by open-pit mining. Between to light gray, and pink with many thin streaks and patches of pink to 1951 and 1953 the deposit was mined by the West Indies Mining Co., purplish iron oxide. Quartz is the most prominent constituent, but which shipped 220,475 tons of ore reported to contain a minimum of 60 various kinds of clay minerals and possibly pyrophyllite have been percent iron (Leovigildo Vázquez, written communication). Most of this tonnage came from the Keystone mine, but a little ore also was lack of subsurface data, no attempt is made in this report to estimate

The Keystone mine consists of an open pit 30 by 170 meters and a small the bottom of the main pit contain considerable gangue as do those of the lower zone exposed to the south. The ore bodies are metasomatic replacements of limestone lenses and calcareous sedimentary rocks. Highly altered, light-colored, volcanic sedimentary rocks and lenses of clayey material separate the lower and upper ore zones at the main pit; another body of clayey material is associated with ore in the open cut to the east. The only plutonic rock exposed at the mine is a pink quartz monzonite(?) dike at the east end of the main pit. Some diorite float also occurs about 100 meters southeast of the main pit. Normal cross faults of small throw The principal ore mineral is magnetite, but hematite, including the specular variety, is common locally. A little malachite, azurite, and chrysocolla are widely disseminated on fractures and in vugs. The chief

gangue minerals are garnet, epidote, and unidentified calc-silicate minerals. Minor quartz and coarse-grained calcite are present locally. The ore bodies occur in a zone that extends from the Keystone mine eastward for 750 meters. East of the mine the bodies seem to be smaller and of a lower grade than those at the mine. Just west of the mine the per, has been carried on intermittently by different companies since unit was found on the western slope of the ore-bearing ridgetop. Many boulders of high-grade ore are scattered along the hill slope just north of Other iron ore deposits in the quadrangle are smaller, rarely exceedazurite are found locally in deposits of iron ore. Some malachite is also Smith, R. J., and Hildebrand, F. A., 1953, Occurrence of alunite and

In the spring of 1959 the Caguas Copper Co. explored several localities in barrios Jaguar and Mamey, Municipio of Gurabo. Trenches that were excavated by this company, table 1, showed malachite, azurite, chrysocolla, and cuprite in addition to the ferrous minerals. Gold and silver occur as trace elements in many of the samples that contain copper (William Bergey, oral communication). The Caguas Copper Co. has not yet released analytical results of sampling of these trenches. An idea of the variability of copper content may be obtained from table 2, which gives the results of "semiquantitative" spectrographic analyses of selected samples collected by the writer. It should be noted, however, that these figures are not reliable for estimating the grade of copper. Crushed stone.-Volcanic sandstone and volcanic breccia are currently quarried in barrio Jaguar. This hard rock is crushed and sieved for use chiefly as road metal. Small quantities of hydrothermally altered rock are occasionally quarried at a small pit at the west end of the Cantagalio ridge for local use as road fill on unpaved roads. Most of the fresh volcanic rocks are suitable for use as riprap and road metal. They are not as good for road metal as limestone, however, because they fracture more readily, are more difficult to crush, and resist compaction. Large quantities of unweathered plutonic rock also

are available for riprap, road metal, and concrete aggregate, but, because these rocks contain fewer joints and fractures than the volcanic rocks, blasting and crushing are more costly. Volcanic rock is therefore preferred for crushed stone. Sand and gravel.—Deposits of sand and gravel suitable for concrete aggregate are common in the banks along the stream channels of the Río Grande de Loíza northwest of and just south of San Lorenzo. Smaller deposits are locally present in the stream channel along the Río Gurabo. Small quantities of sand and gravel have been obtained intermittently for local use from the Río Gurabo just west of El Mango and from the Río Grande de Loíza near the western edge of the map. The alluvialterrace deposits near Juncos also contain much sand, but much of it is silty and too poorly sorted to be of commercial value.

Fettke, C. R., 1924a, Magnetite deposits of eastern Porto Rico: Am. Inst. Mining and Metall. Eng. Trans., v. 70, no. 65, p. 1024-1042. _1924b, The geology of the Humacao district, Porto Rico, in Scientific survey of Porto Rico and the Virgin Islands: New York Acad. Sci., v. 2, pt. 2, p. 117-197. Heidenreich, W. L., 1955, Report on a reconnaissance of mineral deposits in Puerto Rico: manuscript on file at Puerto Rico Econ. Devel. Adm., Roosevelt, P. R., p. 1-17. Meyerhoff, H. A. 1931, The geology of the Fajardo district, Porto Rico, in Scientific survey of Porto Rico and the Virgin Islands: New York Acad. Sci., v. 2, pt. 3. Roberts, H. M., and Crago, W. H., 1945, Report on iron ore deposits in Puerto Rico: manuscript on file at Puerto Rico Econ. Devel. Adm., Roosevelt, P. R.

pyrophyllite in Puerto Rico [abs.]: Geol. Soc. America Bull., v. 64,

no. 12, pt. 2, p. 1476.

Table 2. Analyses of selected samples in the Juncos quadrangle [Lot No. 5062; Report No. TDC-9929] Radiometric and chemical Semiquantitative spectrographic analyses analyses (in percent)2 Laboratory on map sample numbe Total Fe as 91.19 88.54 271,978 32.77 92.24 271,980 70.84 271,987 93.30 33.83 271,974 60.00 29.67 60.79 94.10 80.88 72.95 271,972 2.10 77.18 271,973 16.33 27.75 54 <.0005 0 Elements not looked for: Si, Na, Cs, F, Rb, Yb. Analysts: Lorraine M. Lee and Dwight L. Skinner Analyst: Nancy M. Conklin Additional elements looked for but not found: P, Au, B, Be, Cd, Ce, Dy, Er, Eu, Gd, Ge, Hf, Hg, ³Total iron was analyzed by volumetric method; 0=Element looked for but not found Cu by electroly tic method. Ho, In, Ir, Li, Lu, Nb, Nd, Os, Pd, Pr, Pt, Re, Rh, Ru, Sn, Sm, Ta, Tb, Te, Th, Tl, Tm, U, Y. M = Major constituent—greater than 10 percent Insufficient sample for routine analysis with number = below number shown Figures are reported to the nearest number in the

chrysocolla, goethite(?)

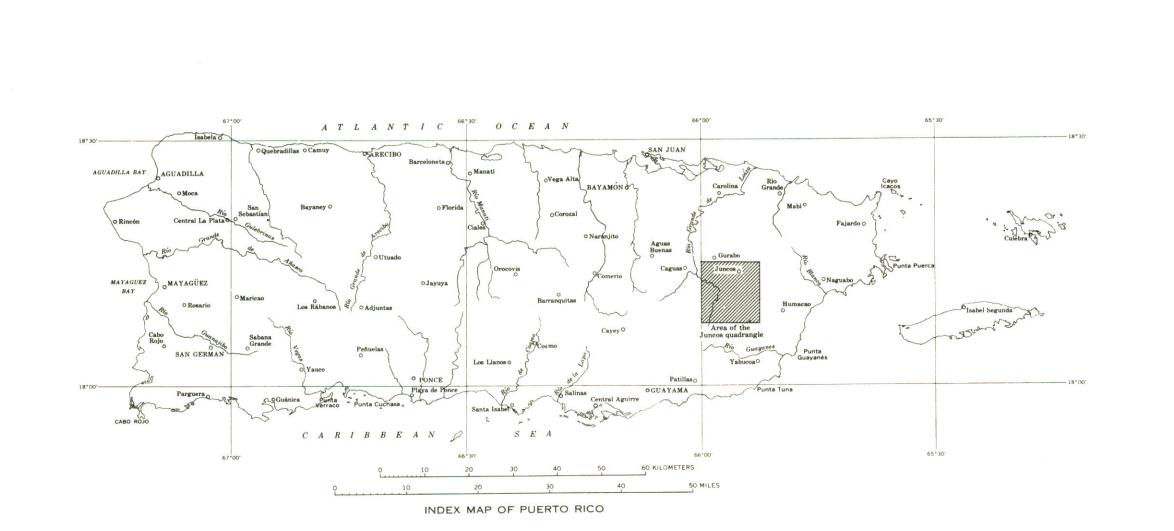
271,983

271,984

Magnetite, hematite

Malachite, limonite

Magnetite



series 7, 3, 1.5, 0.7, 0.3, 0.15, etc. in percent

⁵Au-0.15 troy oz./ton; Ag-1.09 troy oz./ton

Fire assay by Dwight L. Skinner

44,400 209,360

44,510 209,540

44,070 209,590

Outcrop

Outcrop